

3-D AIRFLOW PATTERNS OVER COASTAL FOREDUNES: IMPLICATIONS FOR AEOLIAN SEDIMENT TRANSPORT

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INTRODUCTION

A fundamental criterion for the development of coastal sand dunes is usually highlighted as a significant onshore wind component of the local wind field. The presence of large sand dune systems on coasts where the predominant wind blows offshore is therefore difficult to explain and usually they are attributed to the past occurrence of onshore winds and, by implication, subsequent changes in climate



Recent studies have shown that offshore winds can be deflected or 'steered' locally by the presence of foredunes, inducing a process known as 'flow reversal', whereby the initially offshore wind actually flows onshore at the backbeach. This process is important because it can induce significant aeolian sand transport from the beach and into the dunes, accelerating dune growth. This may be central in explaining the presence of extensive dunes on coasts where the dominant wind is offshore

This work, funded by the UK Natural Environment Research Council (NERC), investigates the controls on the processes and the mechanisms involved in deformation of the flow and resulting sediment transport at coastal foredunes in Northern Ireland. We use a combination of field measurement of wind and sediment transport, coupled with state-of-the-art aerodynamic modelling using computational fluid dynamics (CFD) and 3-D sonic anemometry. Our working hypothesis is that offshore winds contribute substantially to foredune behaviour on leeward coasts

Project Objectives

- Identify structured or systematic turbulence zones (leeward eddies and their behaviour under a range of input velocity fields)
- Examine the relationship between airflow and the position and characteristics of the re-attachment zone in response to incident wind velocity and foredune topography
- Model internal boundary layer characteristics using 3-D CFD modelling (OpenFoam)
- Measure wind flow characteristics using 3-D ultrasonic anemometry
- Assess aeolian sediment transport dynamics within the foredune (dune toe) and back-beach zones using targeted sand trap and impact sensor deployment from 3-D CFD model simulations for optimal instrument locations under a range of airflow scenarios
- Quantify sediment transport using an informed array of high frequency, omni-directional sand traps and grain impact sensors
- Ultimately develop empirical sand transport equations at the site and apply a 3-D CFD model to simulate surface sediment transport

METHODS

- 3D Computational Fluid Dynamics (OpenFOAM)
- 3D ultrasonic Anemometry
- High resolution electronic sand trapping
- Safire granular impact sensors



Computational Fluid Dynamics

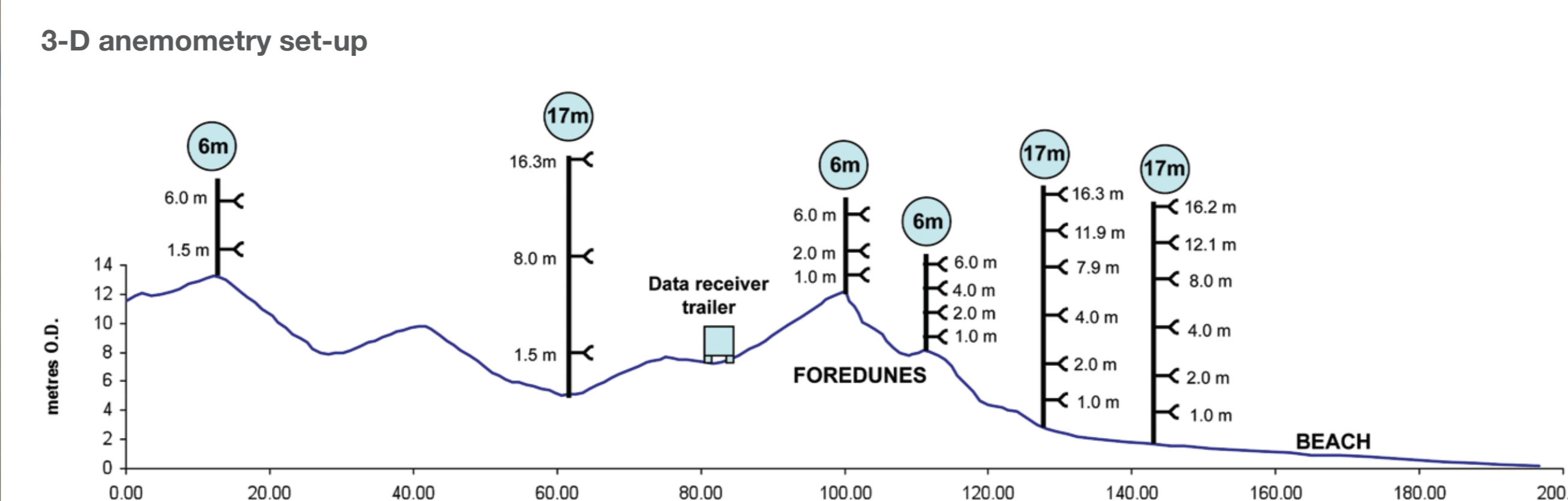
The OpenFOAM CFD model is used to design the field experiments and in turn, the field data is used to refine the model. The accuracy of Reynolds Averaged Navier Stokes (RANS) and Large Eddy Simulations are compared and evaluated. For this purpose the ultrasonic anemometry provide valuable data to compare the results from the different turbulence models applied in these simulations. This includes a comparison of the simulated mean and turbulent fluctuating (rms) velocity components and the measured velocity components. To model sediment transport with CFD both Eulerian and Lagrangian approaches will be used

3-D Anemometry

Achieving adequate spatial coverage of the flow measurement is an important aspect of the project. The airflow will be examined using 3D ultrasonic anemometers (Gill HS-50 model, with an elevation angle from horizontal of +/- 50 degrees, measuring U, V, W output at 50 Hz)



Data is streamed real-time back to an interface system and central control PC in the field



Measuring aeolian (wind-blown) sediment transport

Omni-directional electronic sand traps used to capture sediment flux at 1 Hz

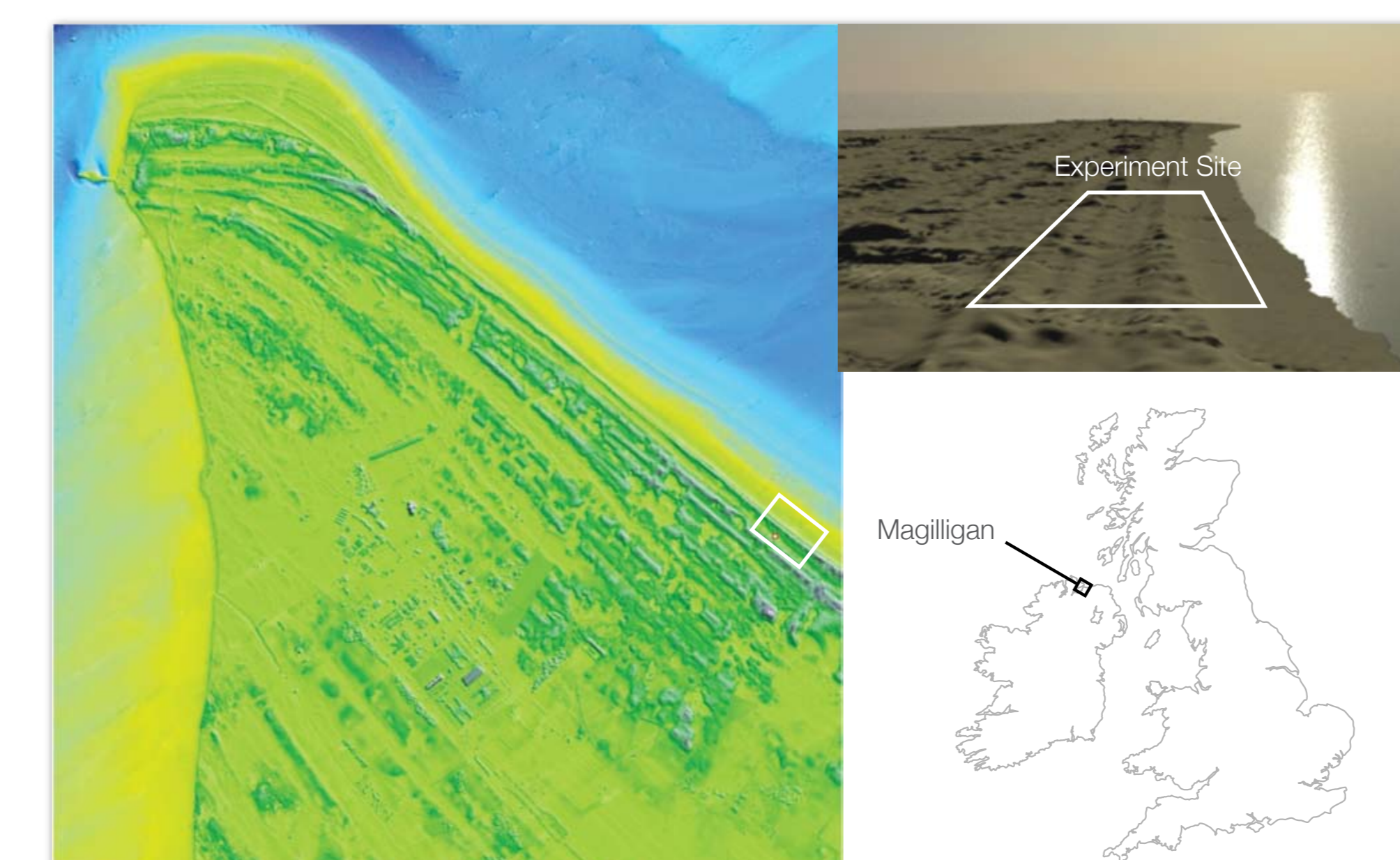
Sixteen traps deployed in a number of arrays to capture temporal and spatial transport patterns according to particular airflow events

Safire impact sensors are used to record intensities of granular collisions against sensitive microphones deployed near the beach surface giving information on event detection

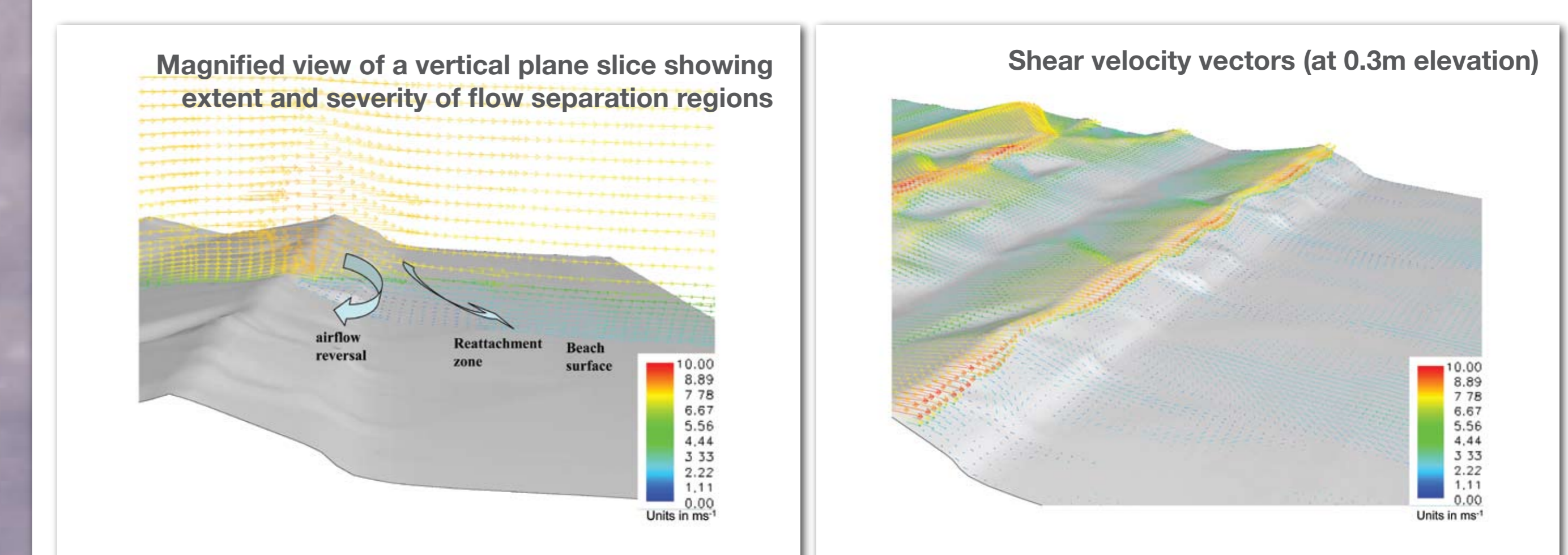
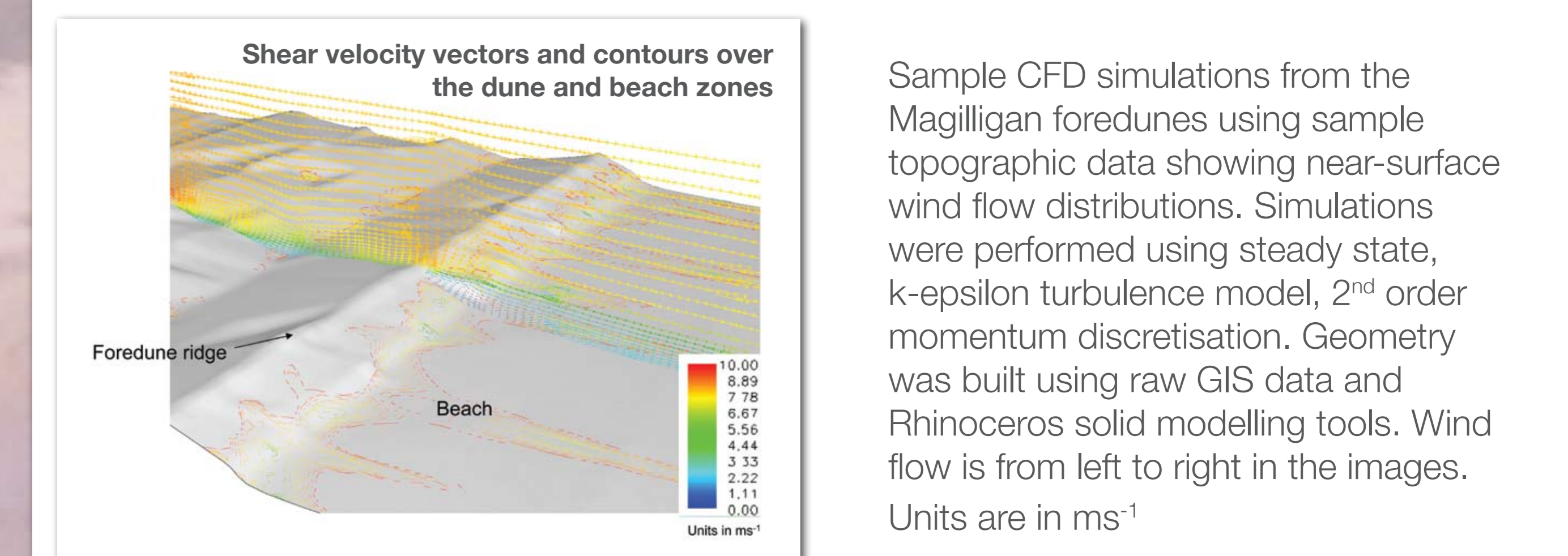
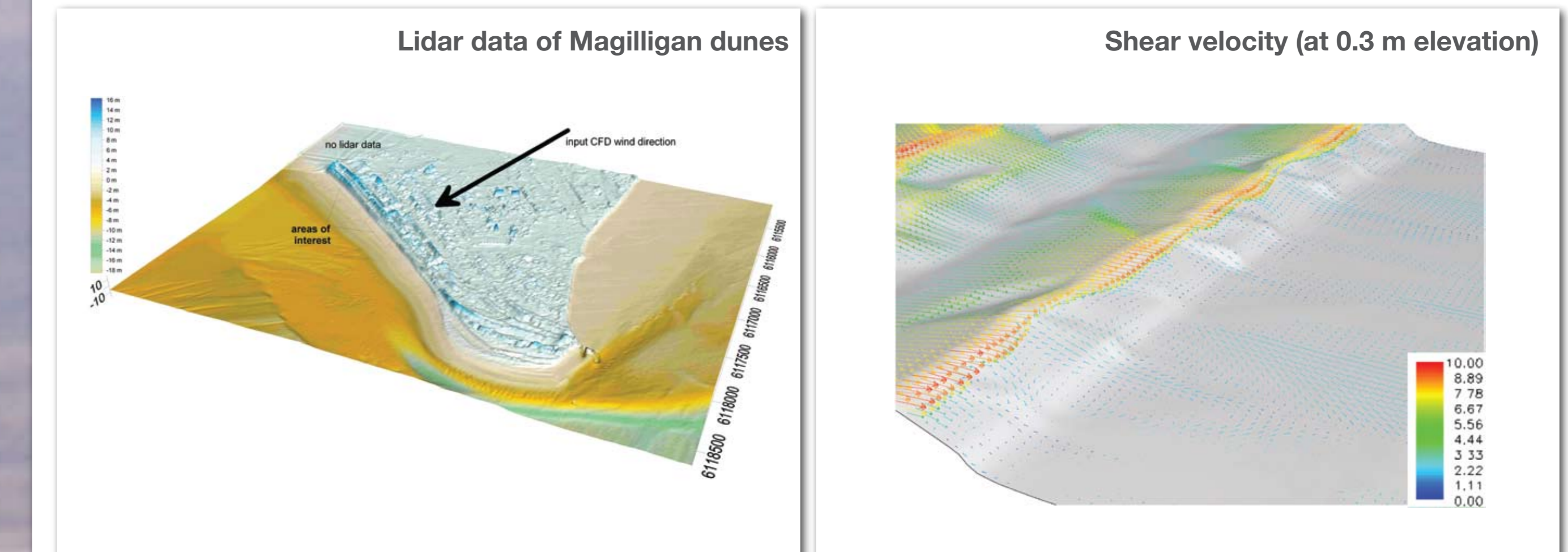
Study Area

Environmental conditions at this location are ideally suited to this study. The dominant winds are from the southwest (offshore), with a foredune crest line running northwest to southeast. The foredune is largely linear and unbroken and approximates the idealised transverse ridges currently used in CFD modelling

The foredunes are of sufficient height (up to 12m above beach level) to induce significant secondary airflow effects and these have been identified in previous work. A range of foredune topographies is present and these will be examined to determine the influence of varying dune shapes on flow reversal



PRELIMINARY RESULTS



- Distinctive aeolian transport partitioning of the beach during offshore winds:
 - Back beach with shore-parallel aeolian transport belt
 - Mid-beach turbulent zone with multi-directional wind vectors and transport phenomena
 - Lower beach offshore directed transport streamers
 - Generation of transport capable onshore wind flow during offshore events
- Clear back-eddy evolution with offshore winds and re-attachment of flow in a transitional zone in the mid-beach area
- CFD model validation using high frequency anemometry in the field shows good agreement between predicted and actual flow data